FIG. 1

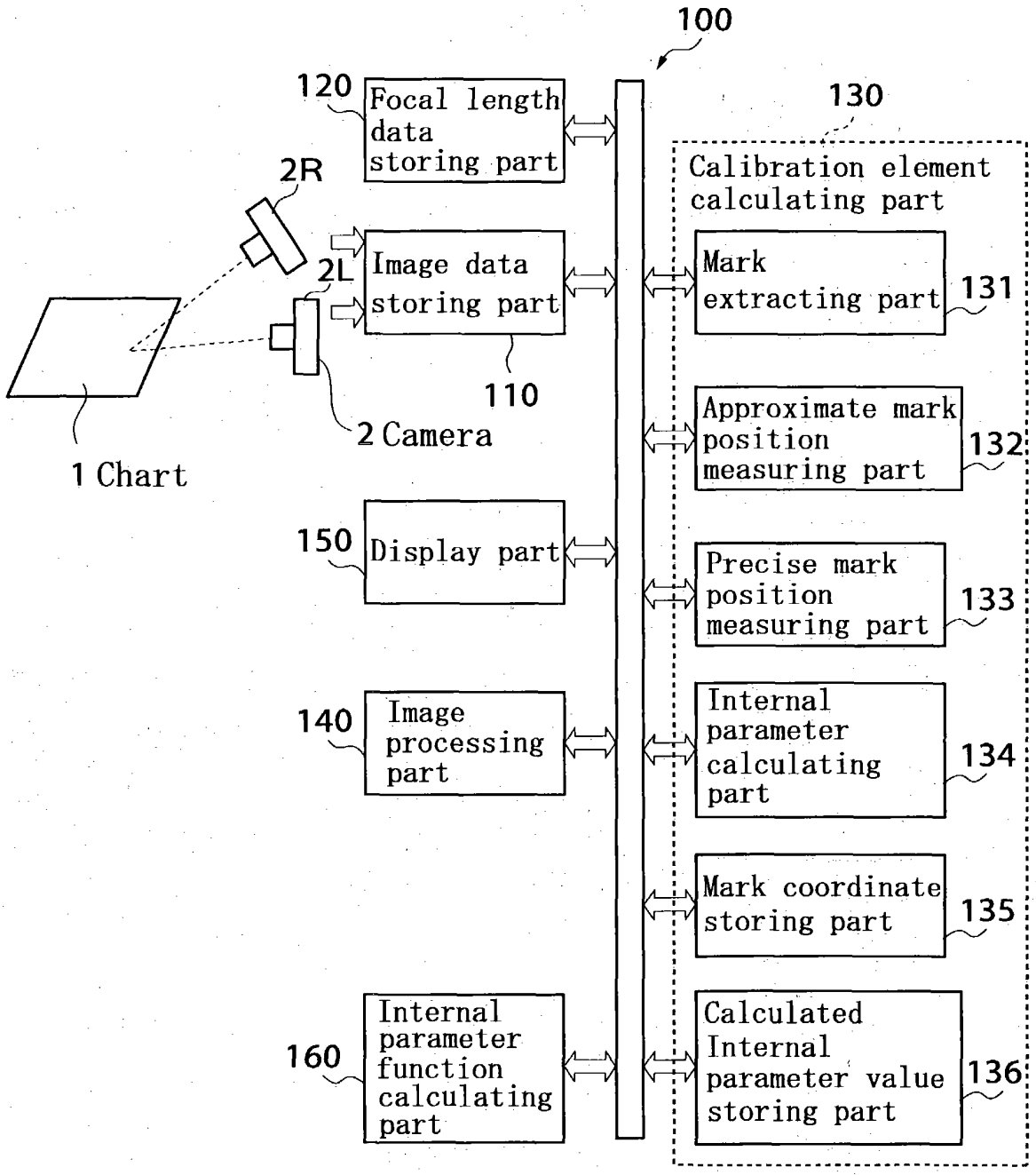
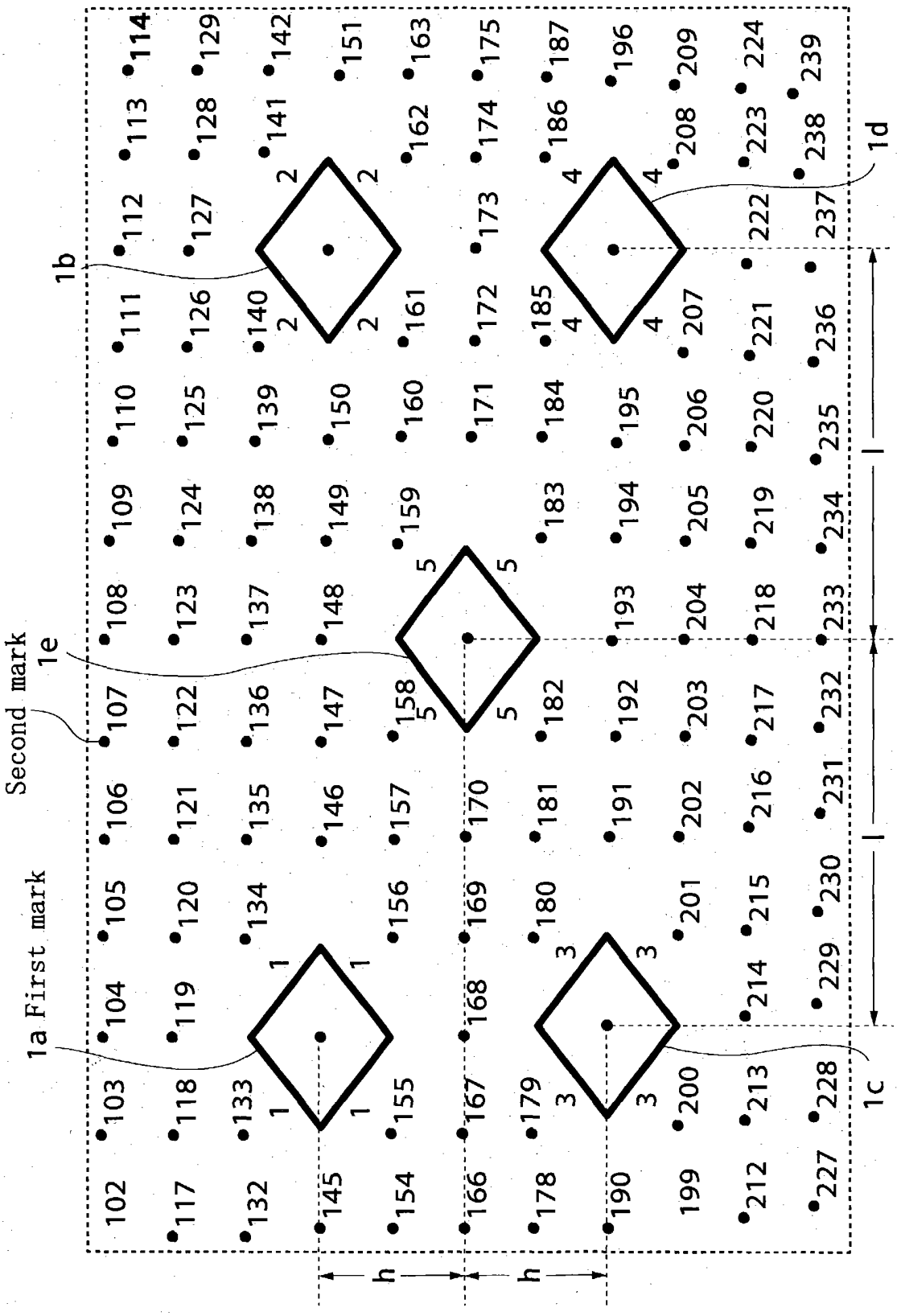

100
120
Focal length data storing part
130
Calibration element calculating part
2R
2L
Image data storing part
Mark extracting part
131
110
2 Camera
1 Chart
Approximate mark position measuring part
132
150
Display part
Precise mark position measuring part
133
140
Image processing part
Internal parameter calculating part
134
Mark coordinate storing part
135
160
Internal parameter function calculating part
Calculated Internal parameter value storing part
136

FIG.2



First mark

FIG. 3(A)

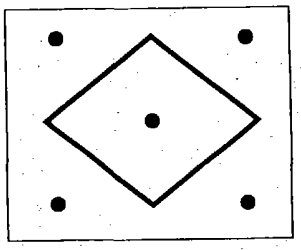


FIG. 3(B)

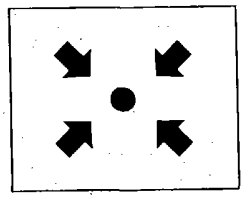
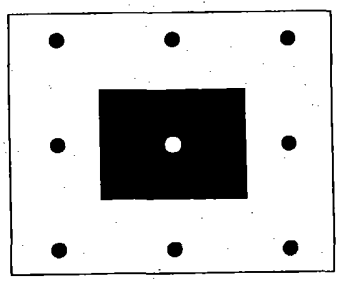


FIG. 3(C)



Second mark

●

FIG. 4(A)

+

FIG. 4(B)

◎

FIG. 4(C)

×

FIG. 4(D)

★

FIG. 4(E)

■

FIG. 4(F)

▲

FIG. 4(G)

◆

FIG. 4(H)

.....

FIG. 5

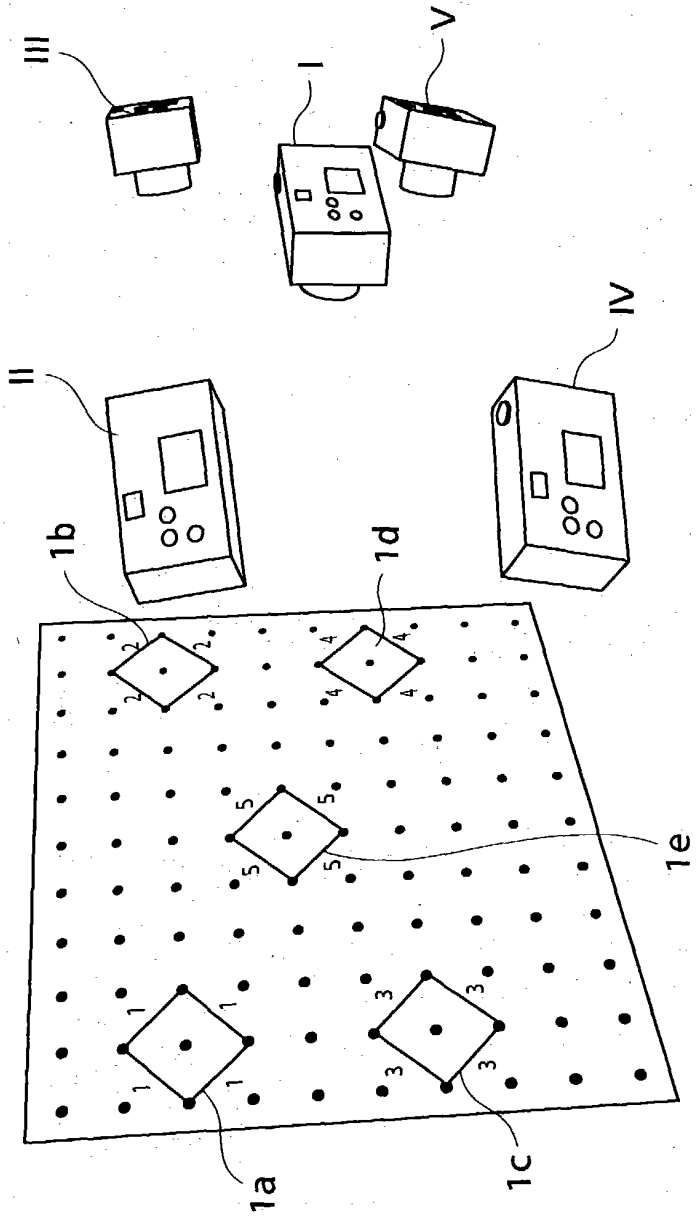


FIG. 6(A)

FIG. 6(B)

FIG. 6(C)

FIG. 6(D)

FIG. 6(E)

FIG. 6(F)

FIG. 6(G)

FIG. 6(H)

FIG. 7

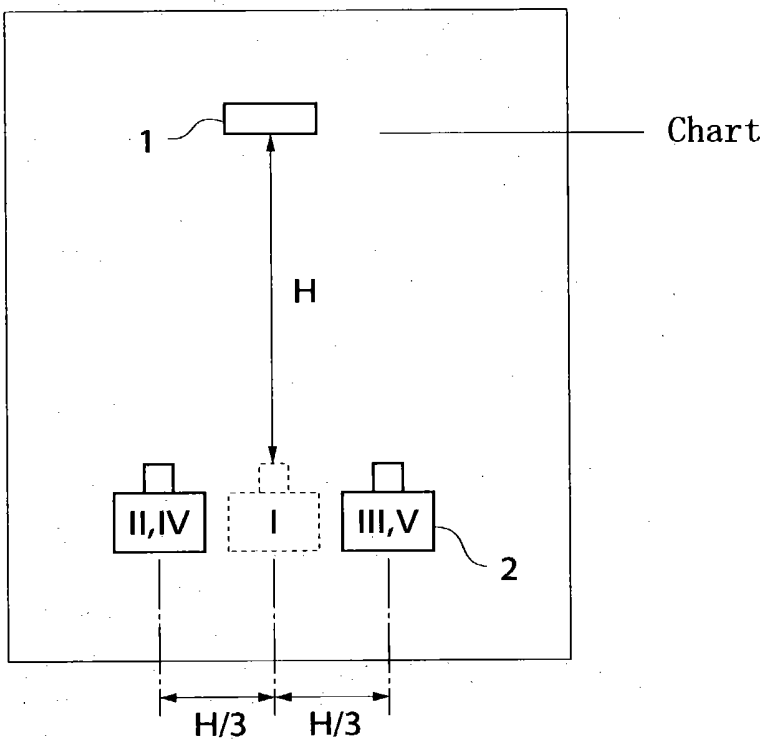


FIG. 8

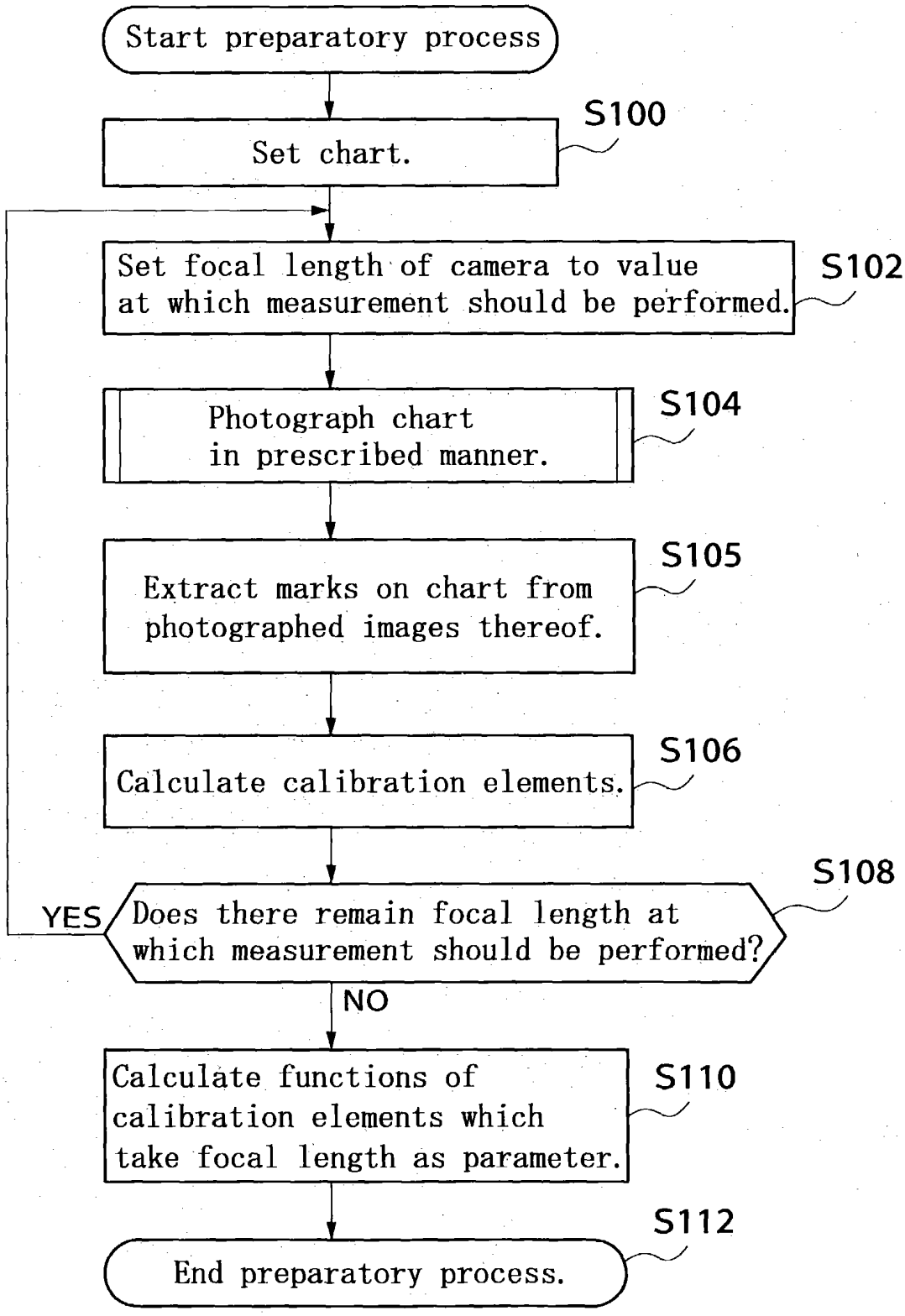

Start preparatory process
S100
Set chart.
Set focal length of camera to value at which measurement should be performed.
S102
Photograph chart in prescribed manner.
S104
Extract marks on chart from photographed images thereof.
S105
Calculate calibration elements.
S106
S108
YES
Does there remain focal length at which measurement should be performed?
NO
Calculate functions of calibration elements which take focal length as parameter.
S110
S112
End preparatory process.

FIG. 9

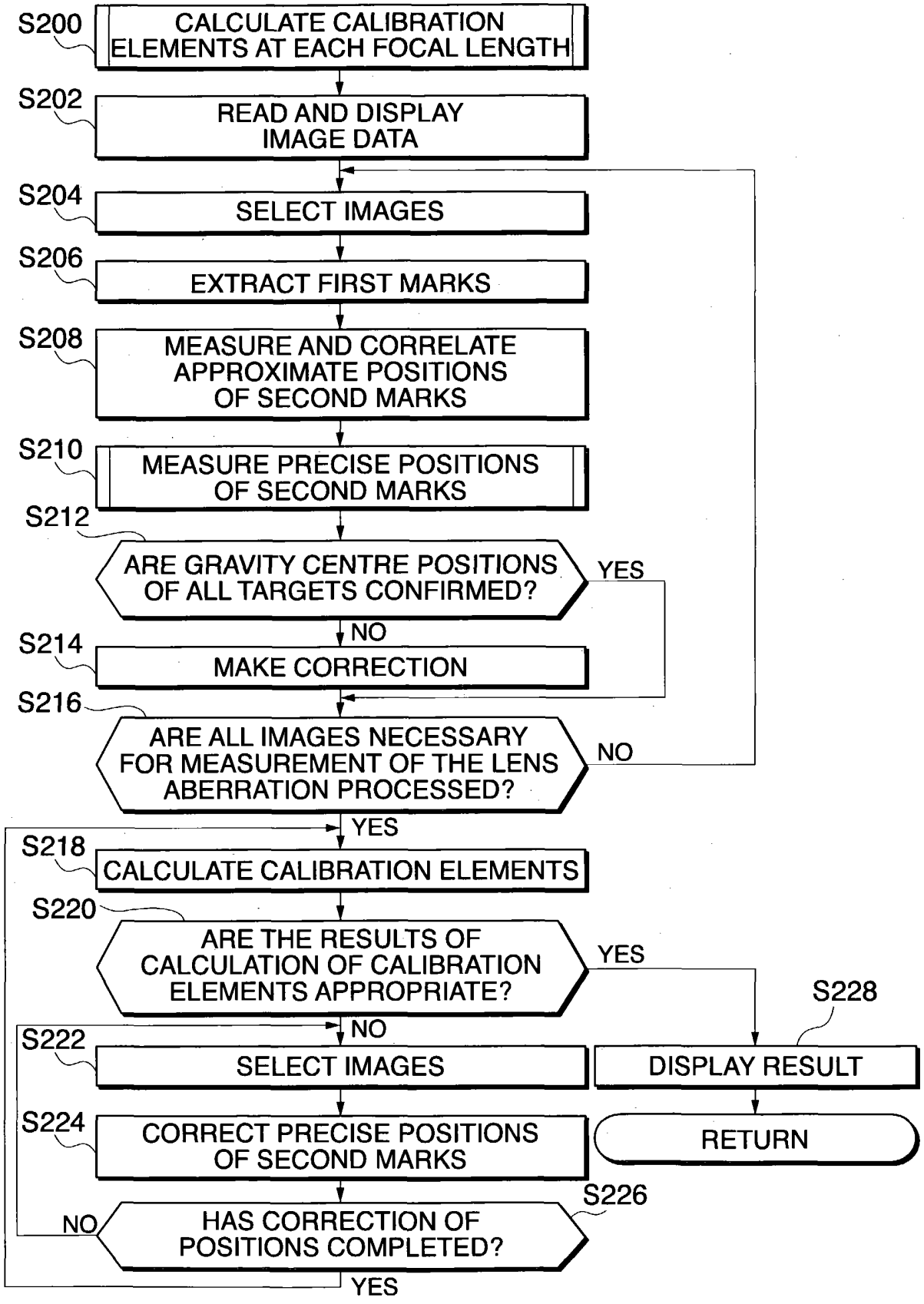

S200
CALCULATE CALIBRATION ELEMENTS AT EACH FOCAL LENGTH
S202
READ AND DISPLAY IMAGE DATA
S204
SELECT IMAGES
S206
EXTRACT FIRST MARKS
S208
MEASURE AND CORRELATE APPROXIMATE POSITIONS OF SECOND MARKS
S210
MEASURE PRECISE POSITIONS OF SECOND MARKS
S212
ARE GRAVITY CENTRE POSITIONS OF ALL TARGETS CONFIRMED?
YES
NO
S214
MAKE CORRECTION
S216
ARE ALL IMAGES NECESSARY FOR MEASUREMENT OF THE LENS ABERRATION PROCESSED?
NO
YES
S218
CALCULATE CALIBRATION ELEMENTS
S220
ARE THE RESULTS OF CALCULATION OF CALIBRATION ELEMENTS APPROPRIATE?
YES
NO
S222
SELECT IMAGES
S224
CORRECT PRECISE POSITIONS OF SECOND MARKS
S226
HAS CORRECTION OF POSITIONS COMPLETED?
NO
YES
S228
DISPLAY RESULT
RETURN

FIG. 10

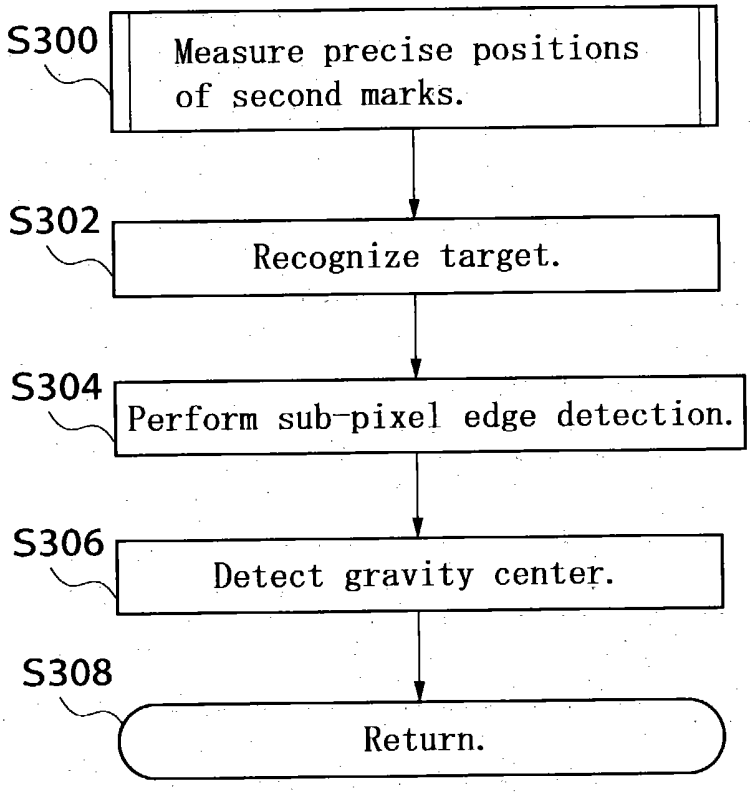

S300
Measure precise positions of second marks.
S302
Recognize target.
S304
Perform sub-pixel edge detection.
S306
Detect gravity center.
S308
Return.

FIG. 11(A)

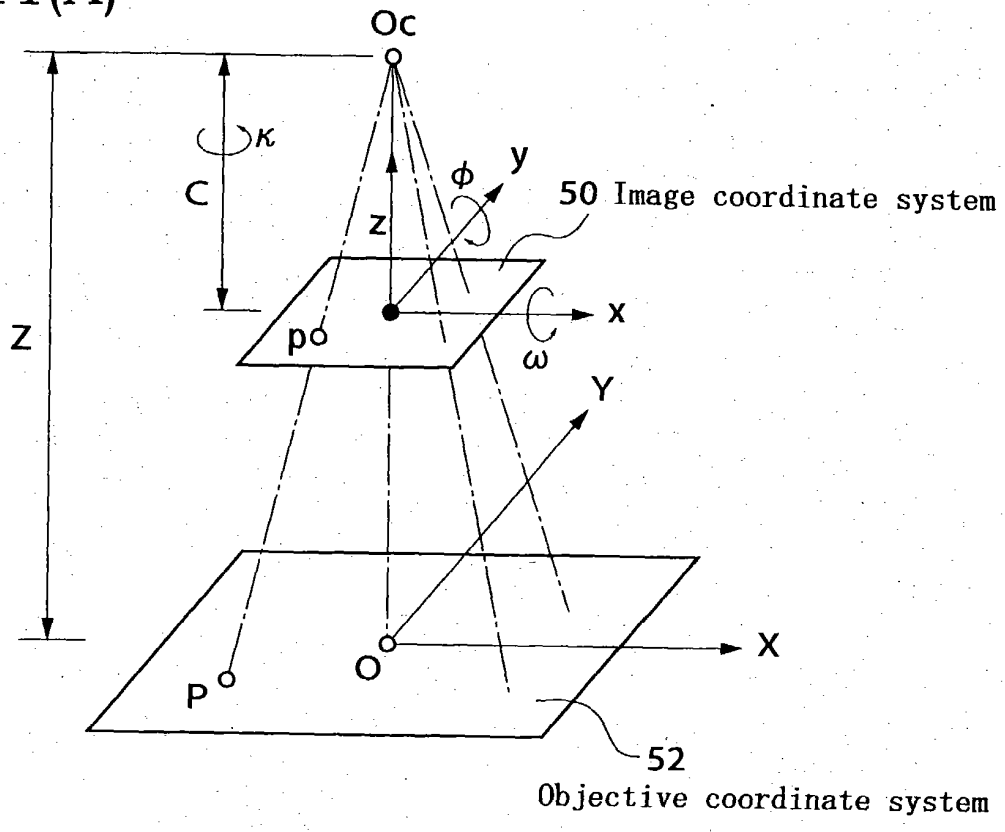


FIG. 11(B)

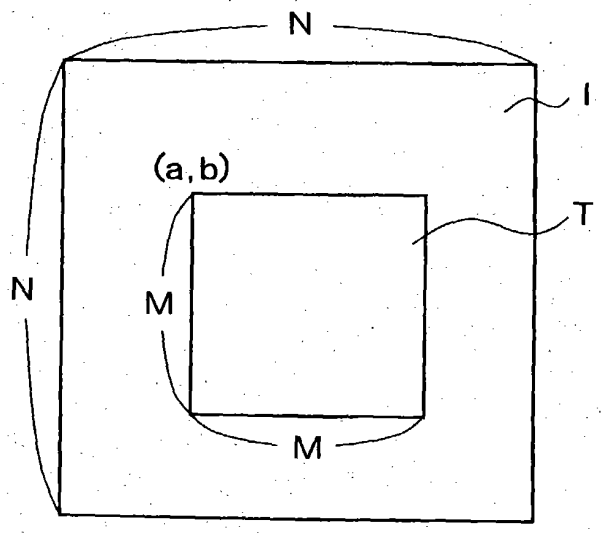
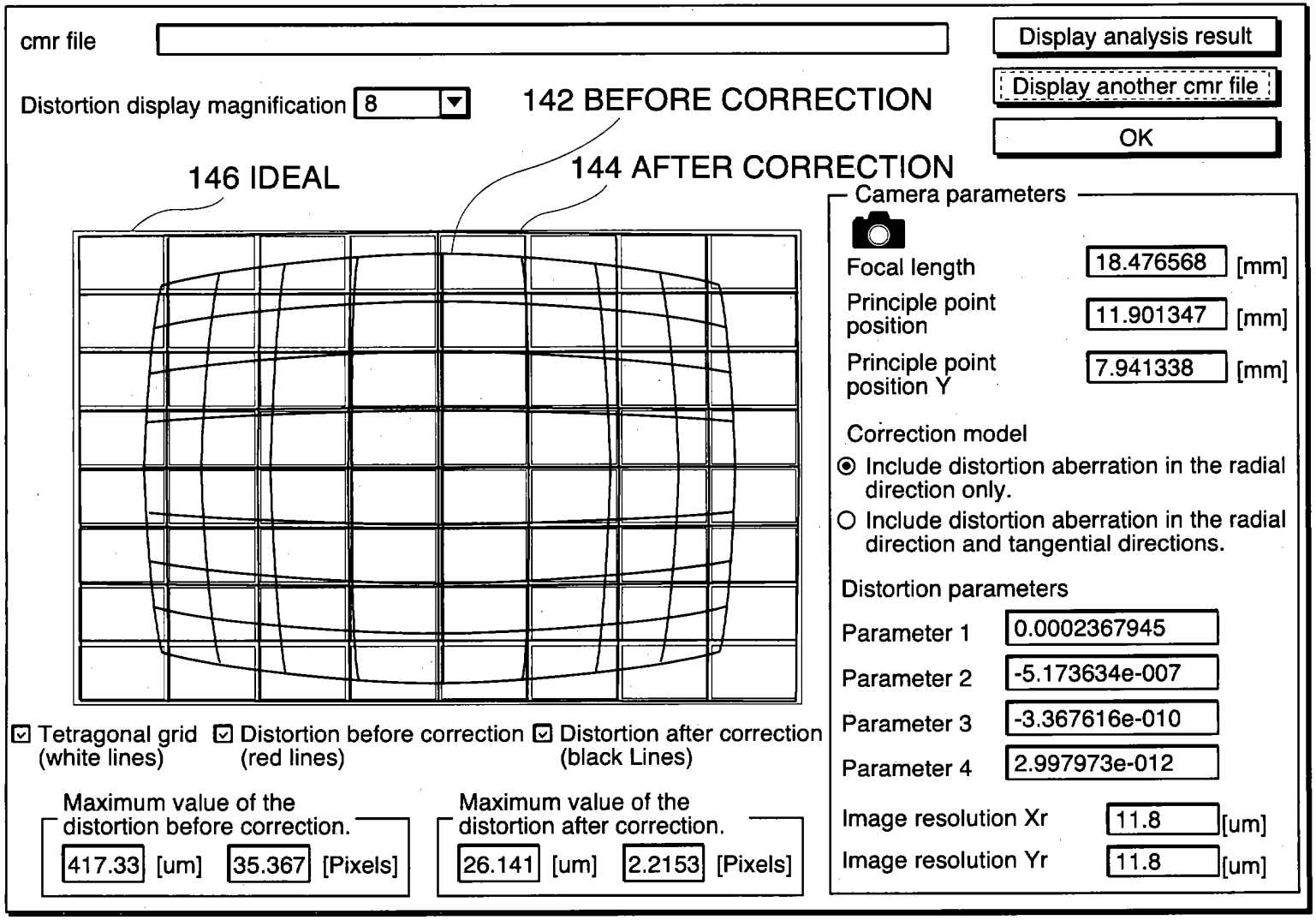


FIG. 12



FOR CALIBRATION, PROGRAM FOR MEASURING DATA FOR CALIBRATION, PROGRAM RECORDING MEDIUM READABLE WITH COMPUTER, AND IMAGE DATA PROCESSING DEVICE
Inventor(s): Hitoshi OTANI et al.
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FIG. 13(A)

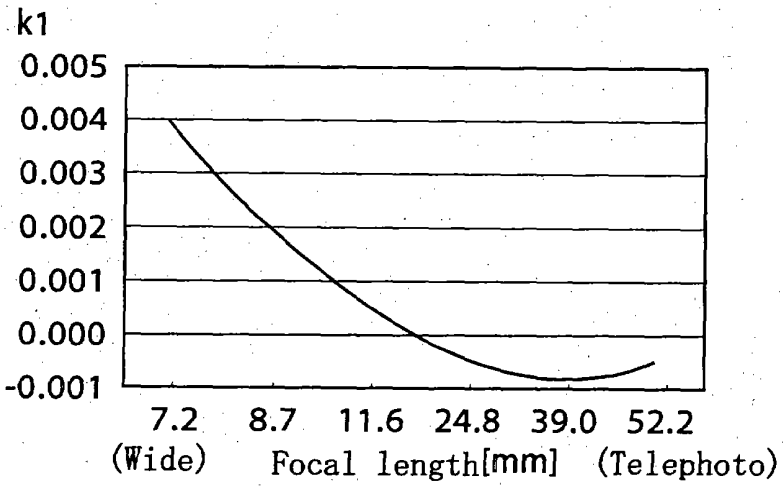
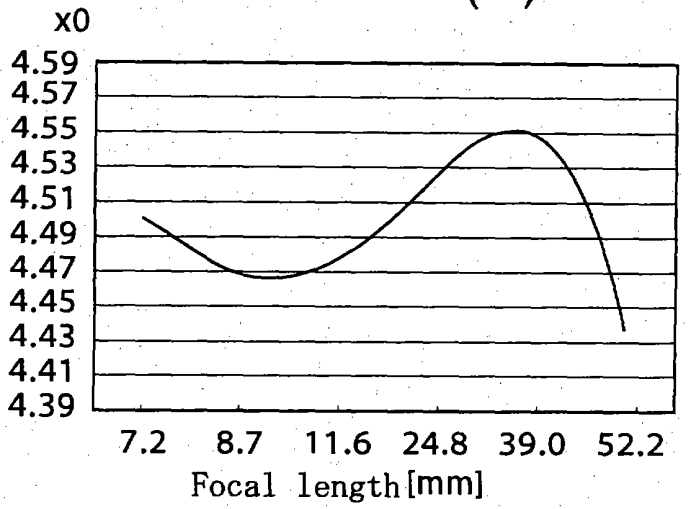


FIG. 13(C)



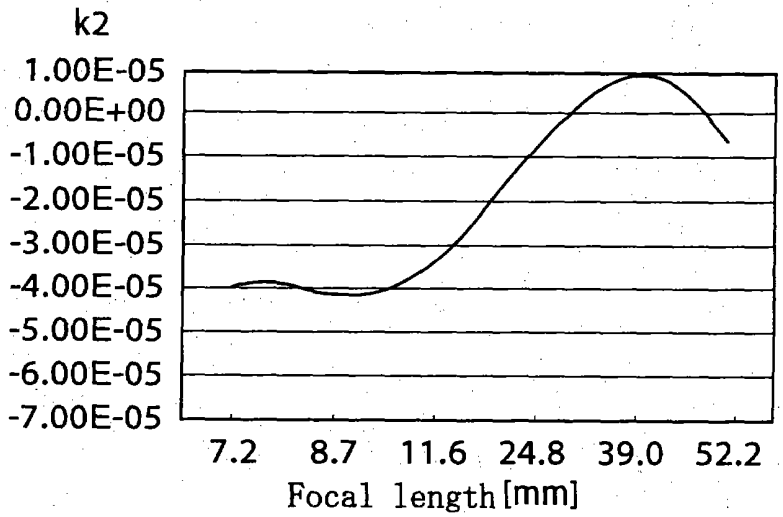


FIG. 13(B)

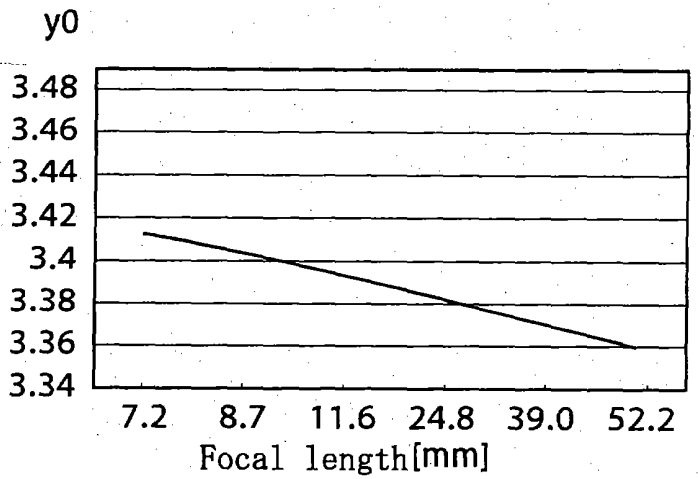


FIG. 13(D)

FOR CALIBRATION, PROGRAM FOR MEASURING DATA FOR CALIBRATION, PROGRAM RECORDING MEDIUM READABLE WITH COMPUTER, AND IMAGE DATA PROCESSING DEVICE
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FIG. 14

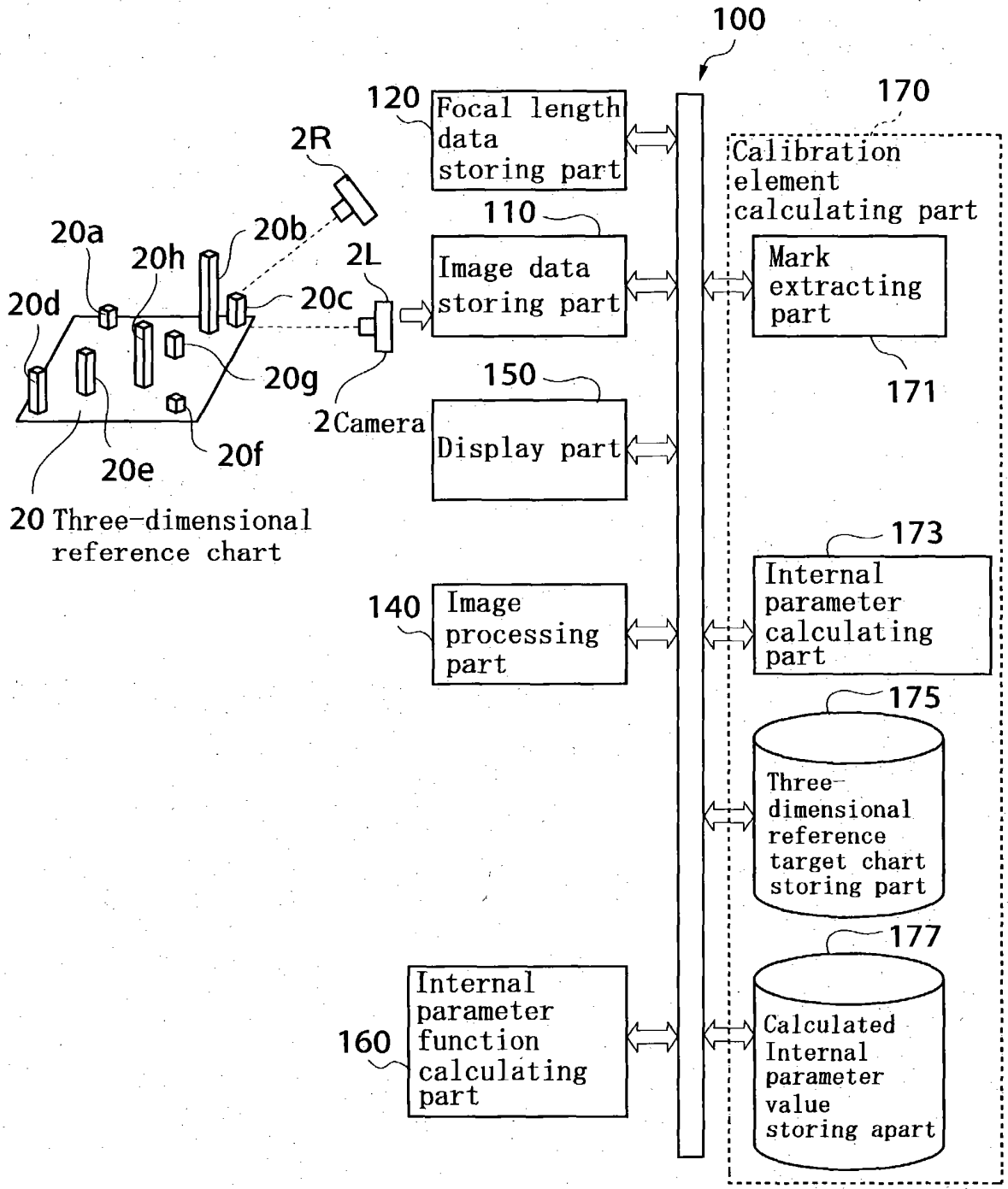
100
120
Focal length data storing part
2R
170
Calibration element calculating part
110
Image data storing part
20a
20h
20b
2L
20d
20c
Mark extracting part
171
150
Display part
20g
2Camera
20e
20f
20 Three-dimensional reference chart
173
Internal parameter calculating part
140
Image processing part
175
Three-dimensional reference target chart storing part
177
Internal parameter function calculating part
160
Calculated Internal parameter value storing apart

FIG. 15

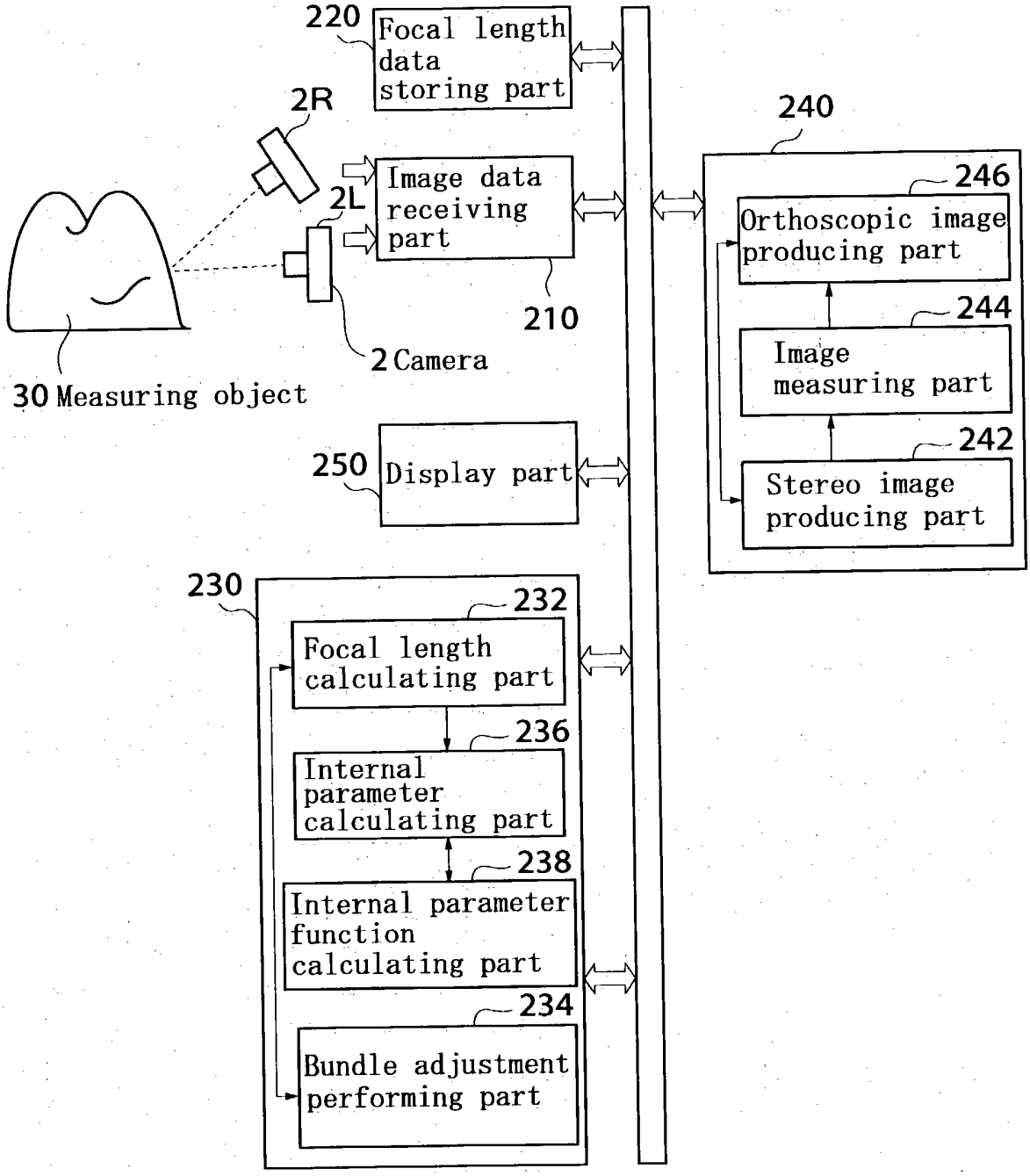
220
Focal length data storing part
2R
2L
Image data receiving part
210
2 Camera
30 Measuring object
240
246
Orthoscopic image producing part
244
Image measuring part
242
Stereo image producing part
250
Display part
230
232
Focal length calculating part
236
Internal parameter calculating part
238
Internal parameter function calculating part
234
Bundle adjustment performing part

FIG. 16

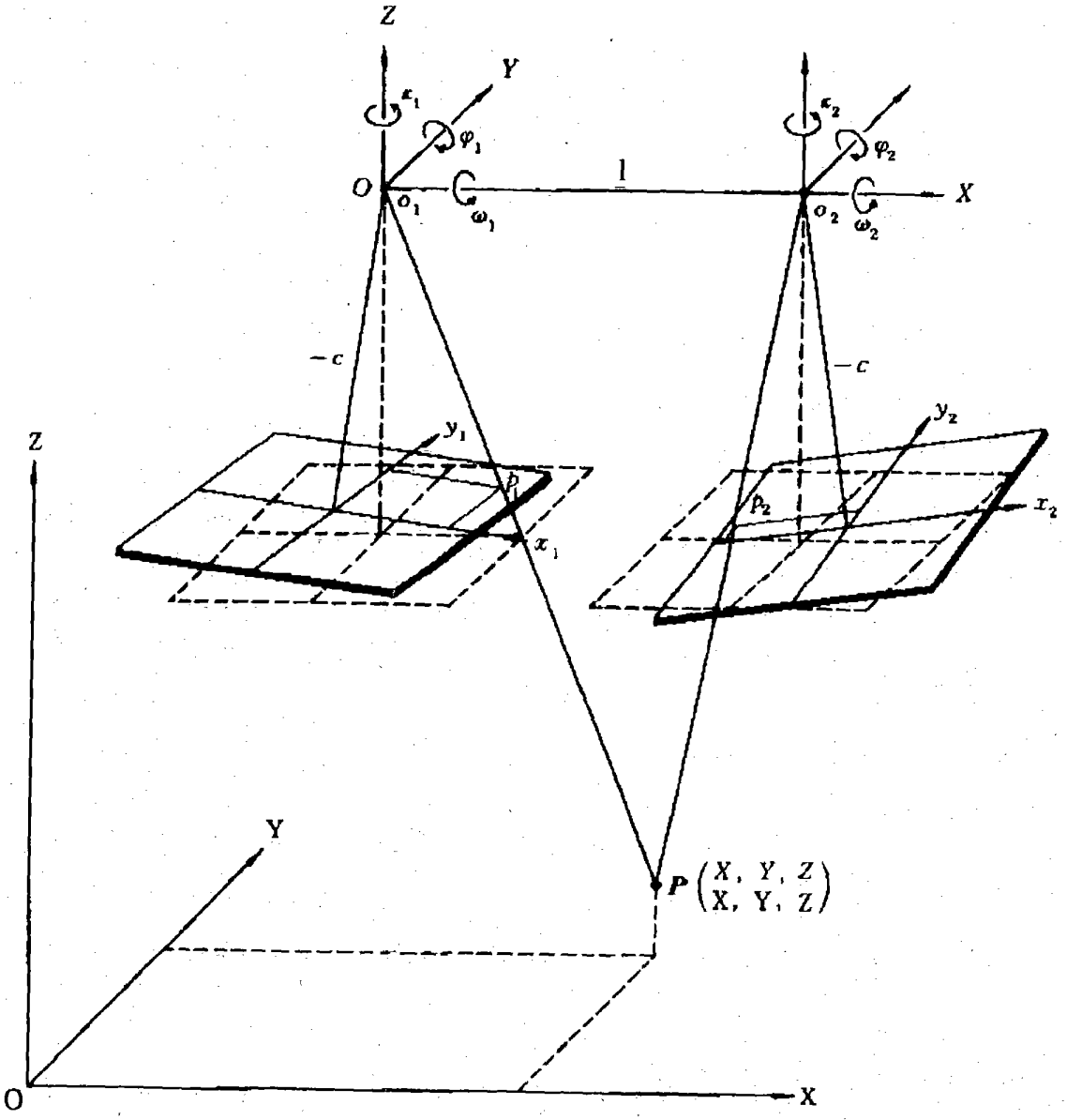
Z
Y
κ_1
φ_1
O
o_1
ω_1
l
κ_2
φ_2
X
o_2
ω_2
−c
−c
y_1
y_2
p_1
p_2
x_1
x_2
Z
Y
P (X, Y, Z) (X, Y, Z)
O
X

FIG.17

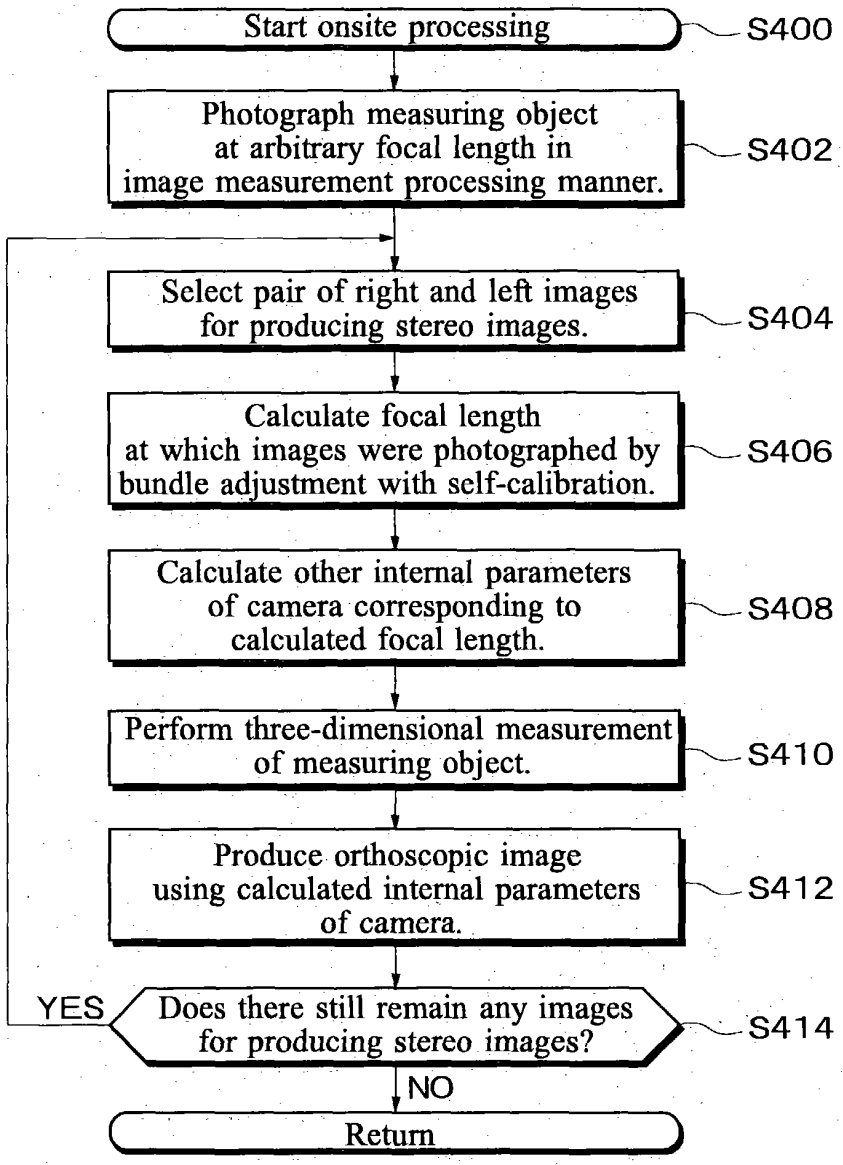
Start onsite processing
S400
Photograph measuring object at arbitrary focal length in image measurement processing manner.
S402
Select pair of right and left images for producing stereo images.
S404
Calculate focal length at which images were photographed by bundle adjustment with self-calibration.
S406
Calculate other internal parameters of camera corresponding to calculated focal length.
S408
Perform three-dimensional measurement of measuring object.
S410
Produce orthoscopic image using calculated internal parameters of camera.
S412
YES
Does there still remain any images for producing stereo images?
S414
NO
Return

FIG. 18

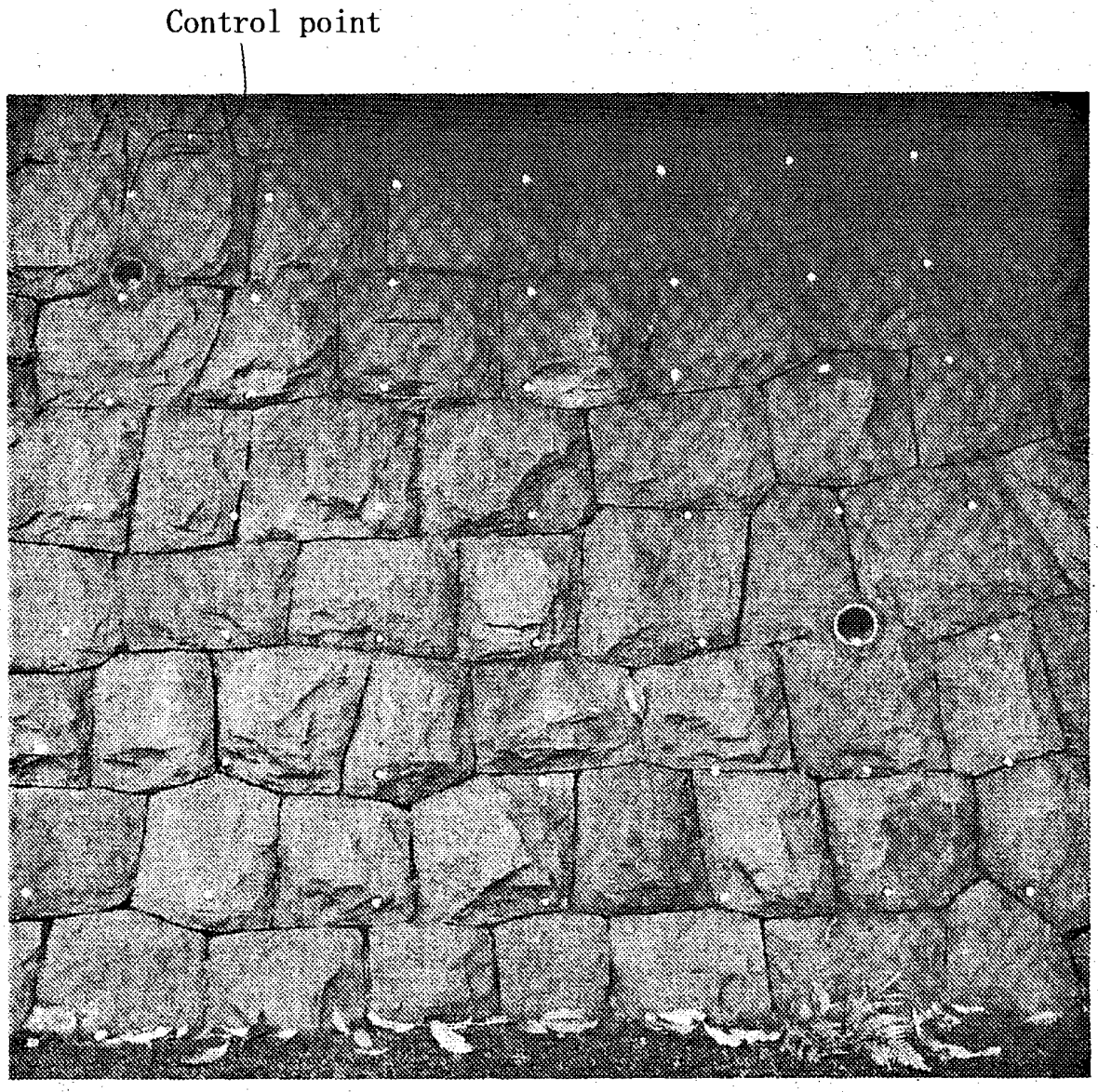

FIG.19

Photographing and analyzing conditions (unit: mm)

	Focal length (approximate value)	Object distance H	Photographing baseline length B
Case 1: Relatively wide	9	2586	774
Case 2: Intermediate	30	6494	1904
Case 3: Relatively telephoto	42	7516	1706

FIG.20

Results of Experiment for Measurement Accuracy

Pattern Focal length	Focal length (analysis value) [mm]	Vertical parallax at mutual localization [um]	Plane accuracy [mm]	Depth accuracy [mm]	σ_{XY} [mm]	σ_Z [mm]
Case 1: Relatively wide (Without correction)	8. 83	1. 5 (8. 8)	0. 7 (8. 4)	1. 4 (13. 5)	1. 0	3. 3
Case 2: Intermediate,approx. (Without correction)	30. 04	0. 8 (6. 7)	1. 3 (9. 6)	1. 8 (15. 2)	0. 7	2. 5
Case 3: Relatively telephoto (Without correction)	43. 21	1. 5 (6. 8)	1. 4 (11. 3)	1. 9 (18. 8)	0. 6	2. 6

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